

## **Data recording device with conducting microtips and production method thereof**

### **5 Background of the invention**

The invention relates to a data recording device comprising at least one electrically conducting microtip having an end designed to be brought into electric contact with a recording medium, the microtip comprising a  
10 longitudinal conducting core having a substantially constant cross-section.

### **State of the art**

15 Memory dot writing and reading techniques by microtips enable very large data storage densities to be obtained.

Several techniques are based on the use of electrically conducting microtips to perform for example local electrical resistivity mappings of a recording  
20 medium. To write or read data, the microtip is brought into contact with the recording medium or close to the latter. Progressive abrasion of the end of the microtips can cause degradation of the performances of the recording device and may result in destruction of the microtip.

25 Numerous types of recording media are proposed for storing data written and/or read from injection of current by means of the microtip. The electric contact surface between the microtip and the recording medium is one of the main parameters controlling the reading resolution and writing density obtained. A small radius of curvature for the apex of the microtip is generally  
30 sought for. Progressive abrasion can cause the electric contact surface between the microtip and the recording medium to be widened and thus

impair the radius of curvature of the apex of the microtip and modify the electrical properties of the microtip losing the desired resolution.

5 Most conducting microtips are based on the silicon technology which enables a microtip apex with a very small radius of curvature to be obtained. One technique, for example, consists in first producing a layer of very highly doped and therefore conducting silicon. The layer is then etched anisotropically to sharpen the microtip. Another technique consists in first producing a non-doped silicon microtip and in covering the microtip with a layer of conducting materials such as nitrides or carbides which are moreover particularly hard materials. Certain techniques use the hardness of diamond to protect the microtip. The microtip is thus covered by a diamond layer, which requires complex fabrication processes presenting high costs.

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15 These devices comprise microtips of pyramidal, conical or truncated-conical shape. These microtips are relatively solid but their electrical properties vary according to the wear process.

20 Certain devices comprise microtips of constant cross-section, which enables electrical properties to be obtained that are independent from the wear process. Such microtips are however very fragile.

25 Moreover, in the case of microtip lattices, to take account of the statistical dispersion of the lengths of the microtips, each microtip is supported by a flexible element, for example a cantilever, which enables all the microtips to be brought simultaneously into contact with the recording medium. Fabrication of the cantilevers does however add complex steps to the production process of the devices.

30 The document WO03/060923 describes a data recording device comprising a cantilever microtip lattice. Each microtip comprises a nanotube salient from

the material of the microtip in which it is inserted. The cantilever material can comprise a polymer or a dielectric material, metals or polysilicon. The tip and cantilever can be delineated by lithography, dry etching or wet etching. The nanotube has a constant cross-section and the cross-section of the microtip material decreases in the direction of the end of the microtip.

### **Object of the invention**

It is one object of the invention to remedy these shortcomings and in particular to provide a device comprising at least one solid microtip, while presenting electrical properties independent from the wear process.

According to the invention, this object is achieved by the appended claims and in particular by the fact that the microtip is surrounded by a sheath made of non-conducting material, so that the free ends of the core and of the sheath are at the same level at the end of the microtip.

It is also an object of the invention to provide a method for production of a data recording device according to the invention, comprising an abrasion step, so that the free ends of the core and of the sheath are at the same level at the end of the microtip.

### **Brief description of the drawings**

Other advantages and features will become more clearly apparent from the following description of particular embodiments of the invention given as non-restrictive examples and represented in the accompanying drawings, in which:

Figures 1 and 2 represent cross-sections of a particular embodiment of a data recording device according to the invention, respectively comprising a non-worn microtip and a worn microtip.

Figures 3 and 4 respectively represent the end of the microtip of the device of figures 1 and 2 in cross-section along the line A-A and along the line B-B.

Figure 5 represents a particular embodiment of a data recording device according to the invention comprising a microtip lattice.

Figure 6 illustrates a particular embodiment of a device according to the invention integrated in a chip also containing the recording medium.

Figures 7 to 11 represent a particular embodiment of a method for production of the data recording device according to the invention.

Figures 12 to 16 represent another particular embodiment of a method for production of the data recording device according to the invention.

### **Description of particular embodiments**

In figure 1, a data recording device comprises a truncated-cone-shaped microtip 1 having one end 2 designed to be brought into electric contact with a recording medium 3. The microtip 1 comprises a longitudinal conducting core 4 having a substantially constant cross-section and surrounded by a sheath 5 made of non-conducting material. The sheath 5 has for example a cross-section that decreases in the direction of the end 2 of the microtip 1. For example, the sheath 5 can have a truncated-cone-shaped or pyramidal part. In the particular embodiment represented in figure 1, the sheath 5 has a plateau, parallel to the recording medium 3, at the end 2 of the microtip 1, and the core 4 has a circular cross-section and is securely affixed to a substrate 6 by means of a conducting track 12. Figure 1 represents the non-worn device.

When several microtips 1 are arranged by means of conducting tracks 12 on the same substrate 6, the substrate can be chosen insulating which enables the microtips 1 to be electrically isolated from one another. In the case of a single microtip 1, the substrate 6 can be chosen conducting and a conducting track 12 is not necessary.

In figure 2, the data recording device of figure 1 is represented after wear. Thus, a part of the microtip 1 has been removed by progressive abrasion of the end 2.

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Figures 3 and 4 respectively illustrate the ends 2 of the truncated-cone-shaped microtip 1 according to figures 1 and 2, without representing the recording medium. The sheath 5 of the end 2 represented in figure 4 is worn and therefore presents a larger external diameter than that of the sheath 5 of the non-worn end 2 represented in figure 3. The diameter of the core 4 is equal in figures 3 and 4.

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The cross-section of the conducting core 4 being substantially constant, the electric contact surface between the end 2 of the microtip 1 and the recording medium 3 is independent from the abrasion process step. The mechanical contact zone between the end 2 of the microtip 1 and the recording medium 3 is defined by the lateral dimensions of the sheath 5. The mechanical contact zone is thus larger than the electric contact surface. The contact force is thus distributed over an increasingly larger zone during the abrasion process and, consequently, the contact pressure is increasingly lower and the speed of the abrasion process decreases as wear progresses, resulting in the surfaces in presence taking exactly the same shape as one another, in particular in the case where there are several microtips.

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The sheath 5 can be formed by an insulating material, for example silica, or by a material having a low conductivity for example by a semi-conducting

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material, so that the resistance of the sheath 5 is substantially greater than the resistance of the core 4. For example, the conductivity of the material of the sheath 5 can be ten times lower than the conductivity of the material of the core 4.

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In a particular embodiment, the core 4 is formed by a carbon nanotube. For example, a carbon nanotube can be grown using a metallic track deposited on a silicon substrate, the metallic track typically comprising a catalyzer, for example a transition metal. For example, a method for growing vertically  
10 aligned carbon nanotubes using plasma enhanced chemical vapor deposition is described in the document "Growth process conditions of vertically aligned carbon nanotubes using plasma enhanced chemical vapor deposition" by M. Chhowalla *et al.* (J. Appl. Phys., Vol. 90, No. 10, 15 November 2001). In this method, the metallic track is fragmented by sintering so as to form  
15 nanometric metallic particles on the substrate. During the chemical vapor deposition, a carbon nanotube grows under each nanometric metallic particle.

The recording device represented in figure 5 comprises a multitude of  
20 microtips 1 arranged as a one-dimensional or a two-dimensional lattice. Their ends 2 generate a substantially flat common surface. Depending on the type of method used for production of the device, the ends 2 can generate a flat or a slightly concave surface, for example a spherical or cylindrical surface. The microtips 1 are respectively arranged on the conducting tracks 12 and are  
25 electrically separated by the substrate 6 the material whereof has a substantially lower conductivity, for example 10 times lower, than the material of the conducting tracks 12.

Figure 6 illustrates a recording device integrated in a dustproof chip 7 and  
30 also comprising a memory disc constituting the recording medium 3. The chip 7 is designed to communicate with a memory reader by means of a plurality

of electric contacts 8 arranged outside the chip 7. An exchangeable memory is thus obtained comprising a read head formed by the microtips 1. The reader also comprises actuators to ensure relative movement of the read head and of the recording medium 3. For example, a motor can drive the memory disc and a radial translation unit can move the read head along the memory dot lines chosen on the disc. The amplitude of movement of the translation unit is for example greater than or equal to the linear pitch between two adjacent microtips 1, for example comprised between 10 $\mu$ m and 100 $\mu$ m.

The space between the microtips 1 and the recording medium 3 can be filled by a lubricant having a low conductivity, for example by graphite, silicone or a liquid, which ensures the electrical conduction between the microtip 1 and the recording medium 3. The electrical conductivity of the lubricant must be sufficiently low not to create a short-circuit between adjacent microtips 1 (Z-DOL or graphite or silicone type lubricant).

A method for producing a data recording device according to the invention comprises, after assembly of the constituent materials respectively the core 4 and sheath 5 of a microtip 1, an abrasion step so that the free ends of the core 4 and of the sheath 5 are at the same level at the end 2 of the microtip 1. The abrasion step is preferably performed by mechano-chemical planarization. On account of the statistical dispersion of the lengths of the bodies before abrasion, all the materials constituting the bodies 4 and the sheaths 5 can for example be polished until the thickness of the assembly corresponds for example to half of the mean length of the bodies 4.

A method for production of a data recording device according to figure 5 comprises the steps represented in figures 7 to 11.

The first step consists, as represented in figure 7, in depositing a layer 9 of conducting material on a substrate 6. The conducting material can be polycrystalline silicon, carbon or a metal and the substrate 6 is for example made from silicon covered with silica. Deposition of the layer 9 can be performed by a conventional process such as sputtering or chemical vapor deposition.

The substrate 6 has been previously provided with conducting tracks 12 by deposition of a metal layer, for example made of copper, etched by any photolithography and etching process. The bodies 4 are deposited on these conducting tracks 12 in the following steps.

The second step consists, as represented in figure 8, in etching the conducting material of the layer 9 through a mask so as to form pillars 10 designed to each constitute a core 4 of a microtip 1.

Then in a third step, illustrated in figure 9, a layer 11 of the non-conducting material designed to form the sheath 5 is deposited on the substrate 6 provided with the pillars 10. The different deposition methods depend on the non-conducting material chosen. Thus a layer of carbon of diamond like carbon (DLC) type can be deposited by chemical vapor deposition from methane or carbon monoxide, a layer of  $\text{Si}_3\text{N}_4$  can be achieved by sputtering and a layer of  $\text{SiO}_2$  can be obtained by spin coating of silica obtained by a sol-gel type process. The deposition thickness of the layer 11 of the non-conducting material represented in figure 9 is chosen such that the pillars 10 are completely immersed in the layer 11. However, it is also possible to deposit a layer 11 the thickness of which does not exceed the height of the pillars 10.

Then a fourth step consists, as represented in figure 10, in performing the abrasion, as described above, so that, at the end of abrasion, the free ends



of the pillars 10 and of the sheaths 5 are at the same level at the end 2 of each microtip 1.

In a fifth step, represented in figure 11, the non-conducting material of the layer 11 is etched so as to delineate the sheath 5 laterally. The mechanical contact zone between the end 2 of the microtip 1 and the recording medium 3 can therefore be reduced and the friction forces are therefore reduced. The layer 11 is etched between the bodies 4, in a gap of predetermined width that is smaller than the distance between two bodies 4, over a predetermined depth which does not necessarily correspond to the thickness of the layer 11. In this way, the sheath 5 of each microtip represented in figure 11 obtains a constant cross-section at the end 2 of the microtip, whereas near to the substrate 6, the layer 11 covers the complete space between the pillars 10. Etching can be performed by chemical means or by ion bombardment. The etching step also comprises lithographic masking.

A single microtip or any two-dimensional or one-dimensional lattice of microtips can be achieved by a method similar to the method described above.

Whereas in the method represented in figures 7 to 11, the bodies 4 are produced before the sheath 5, in another embodiment, the sheath 5 is produced before the bodies 4. In all cases lithography or a self-organization process can be implemented to delineate the bodies 4.

In the case where the core 4 is fabricated first, for example by etching of a conducting material (figure 8) or by local growth in the case of carbon nanotubes, the diameter of the core 4 thus obtained may have to be reduced, which can be done by an isotropic reactive etching step. Deposition of the sheath 5 (figure 9) can then be performed by physical vapor deposition, the case of an amorphous graphite for example, by chemical vapor deposition,

the case of silica, nitrides or diamond like carbon, or by a sol-gel type method, for example by dip-coating.

Figures 12 to 16 illustrate a fabrication method in which the sheath 5 is produced before the core 4. The microtips 1 are achieved on a substrate 6 comprising for example conducting layers 12 and a planarization layer 15. A layer 13 of a material designed to constitute the sheath 5 is deposited by any method, for example by one of the methods mentioned above. Then, as represented in figure 12, pass-through holes 14 are etched in the layer 13. To reduce the size of the holes 14 thus obtained, a material 16 is deposited on the front surface of the sheaths 5, on the walls of the holes 14 and on the bottom of each hole 14. Anisotropic etching then enables the material 16 to be removed from the bottom of each hole 14 and from the front surface of the sheaths 5 (figure 13).

The core is then produced by any envisageable deposition method of a conducting material such as tungsten or by deposition of a catalyzer, such as nickel for growth of carbon nanotubes 17 from the bottom of each hole 14, as represented in figure 14. In the latter case, the hole is filled with an additional material 18, for example by electrolytic deposition of a conducting material, for example tungsten, copper or nickel. Then, as represented in figure 15, abrasion of the front surface of the stack enables uniform lengths of the bodies 4 formed by the carbon nanotubes 17 to be obtained. Then the sheath 5 is etched over a predetermined depth, for example over its whole depth as represented in figure 16 or over an intermediate depth as represented in figure 11.

The method according to the invention enables a microtip lattice 1 to be obtained the ends 2 whereof form a substantially flat common surface, which enables all the microtips 1 to be brought simultaneously into contact with the

recording medium 3 without needing flexible elements such as cantilevers to compensate length differences of the microtips 2.

5 The microtip lattice can be used as a two-dimensional matrix by similitude with the millipede<sup>®</sup> solution of the IBM corporation, or as an array for use with a memory in the form of a rotary disc. In the case of a rotary disc, the recording medium 3 can for example be made of plastic.

10 The invention is not limited to the embodiments represented. In particular, the sheath 5 can have an outside wall of any shape. For example, the wall can have a cylindrical or square cross-section. The microtip 1 according to the invention can also be arranged on a cantilever, obtained for example by etching after the microtip has been produced.